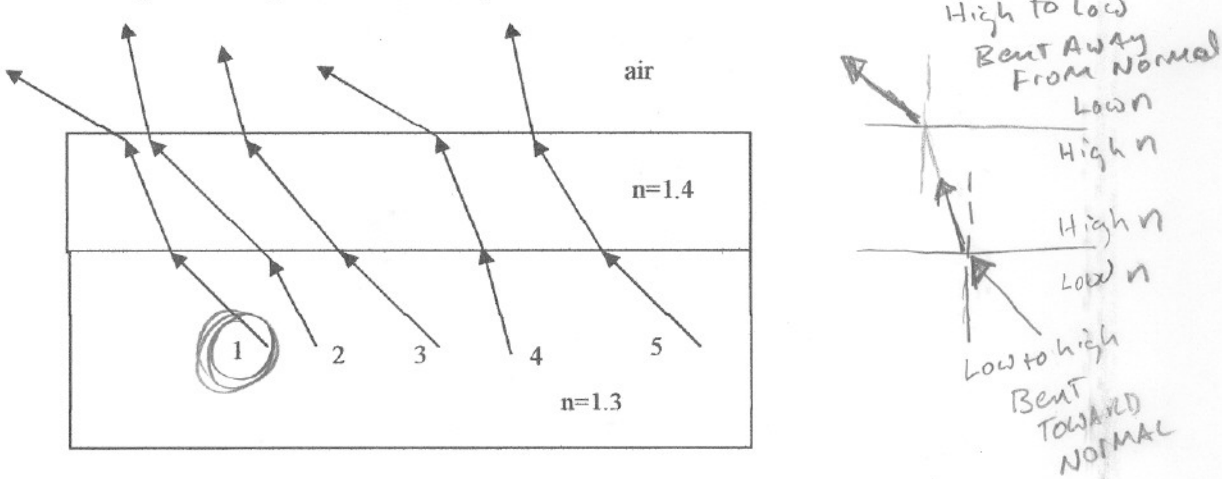
Exam 3 (April 20, 2004)

Please read the problems carefully and answer them in the space provided. Write on the back of the page, if necessary. Show all your work. Partial credit will be given unless stated otherwise.

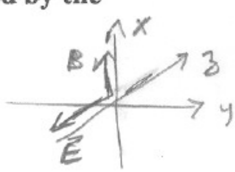
Problem 1 (8 pts, no partial credit given):

Light travels from from a medium with index of refraction of 1.3 into one with index of refraction of 1.4 and from there into air. Circle the number of the ray that corresponds to the one most like the path the light would actually take.



Problem 2 (12 pts, show work/logic for parts a and b to get credit, no need to justify parts b and c):

The magnetic field in an electromagnetic wave from a distant source is described by the equations $B_x = B_o \sin(ky+\omega t)$, $B_y=0$, $B_z=0$.



a) What is the direction of propagation of this wave?

Going in -y direction because Arguement of Sin is $(ky+\omega t)$

b) Write the electric field equations for this wave.

$E_z = -cB_o \sin(ky+\omega t)$, $E_y = 0$, $E_x = 0$

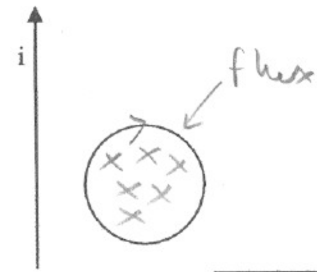
c) Does the wave exhibit linear or circular polarization? Linear

d) If the polarization is linear, in what direction is the wave polarized?

in The $\hat{z}$ Direction Axis

Problem 3 (8 pts, show work/logic to get credit):

Suppose the magnitude of the current shown is decreasing with time. What is the direction of the induced current in the loop? Please justify your answer to get credit. (*Assume the loop and the line are in the same plane.*)



By RH Rule - $\vec{B}$ due to wire current gives flux going into paper thru loop. That Flux is Decreasing because the current is Decreasing. So, By Lentz's Law the current induced in the loop will be clock wise because that would act to increase the ~~curren~~ Magnetic flux in the loop.

1)	/8
2)	/12
3)	/8
4)	/15
5)	/12
6)	/15
7)	/15
8)	/15
tot	/100

Problem 4 (15 pts, show work/logic to get credit):

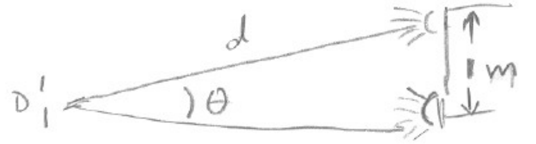
Briefly explain why it is that sound waves seem to bend around corners and light waves do not? Feel free to use diagrams to facilitate your explanation.

Both light and sound are wave phenomena. Both will exhibit Diffraction when going thru a "slit" or past an edge. Since the wavelength of Sound is much larger than that of light (mm to m rather that 10^{-7} m), the Diffraction of sound by a Macroscopic object is much larger than for light. Consequently sound is "bent" Around a corner to a much larger degree than light.

Problem 5 (12 pts, show work/logic to get credit):

The pupil of the human eye has a diameter of 5 mm. Estimate (using the physics we have been discussing) the greatest distance over which a human can resolve the two individual headlights of a car.

Make use of Rayleigh's Criterion $\theta \sim 1.22 \frac{\lambda}{D}$ = Minimum Angle where 2 objects can be resolved



$\theta \sim 1.22 \frac{550 \times 10^{-9}\,m}{0.005}$ ← Middle of Visible light range

$\theta \sim 0.00013$ rads

Let car lights be separated by 1 meter

$(1m) = d\theta$ $d = \frac{1}{.00013} \approx 7400\,m$

Problem 6 (15 pts, show work/logic to get credit):

A crude, symmetric, hand-held microscope consists of two 20 diopter lenses fastened in the ends of a tube that is 0.3 m long.

a) What is the magnifying power of this microscope?

For Microscope want image of objective to be at focal point of eyepiece

$\frac{1}{f} = \frac{1}{i} + \frac{1}{o}$ $f = \frac{1}{20} m = 0.05\,m$ $\frac{1}{.05} = \frac{1}{0.2} + \frac{1}{o}$ $o = 0.067\,m$

$i = 0.3 - (2)(.05) = 0.2$ → places image at f of Eyepiece

b) How far from the objective should the object being viewed be placed?

Magnification of Objective $= -\frac{i}{o} = -\frac{0.2}{0.067} \approx -3$

Magnification of Eyepiece $= \frac{\text{Normal PT}}{F} = \frac{.25}{.05} = 5$

TOTAL Magnification = -15

* **c) Suppose you discover that your grandfather literally was Superman and that you have inherited X-ray vision. After tiring of looking thru the clothes of all your classmates, you eventually decide to use the microscope above. (No need to look around right now, this is fictitious.) Will the microscope work for X-rays the same as it does for visible light? Why or why not?**

Does not work for X-rays because the index of refraction of glass depends on the wavelength of the light (dispersion). An optical configuration that works at one range of wavelengths is unlikely to work well in a very different range.

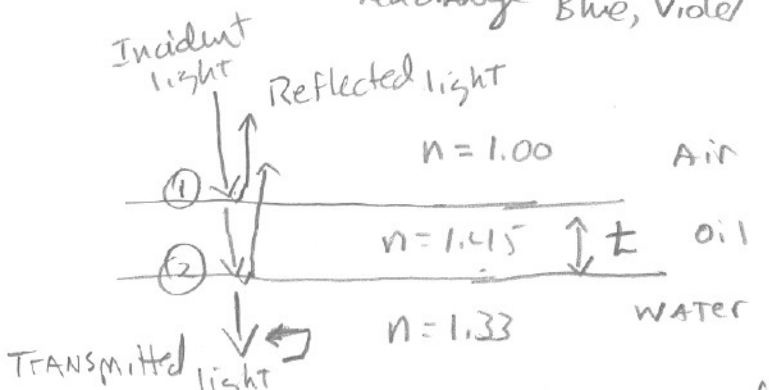
P114 University of Rochester NAME Soln key – Slm
S. Manly Spring 2004

Problem 7 (15 pts, show work/logic to get credit):

You go swimming with clear goggles in a pool of clear water that has a layer of oil 540 nm thick spread evenly on the surface. Assume white light is incident normally on the top surface of the pool. To you, as you swim underwater, ~~will the water appear more blue or less blue in color than it normally appears without the oil present~~? (You must defend your answer quantitatively to get full credit.) ***Assume the index of refraction of the oil is 1.45 and the index of refraction of water is 1.33. The wavelengths present in visible light range from 700 to 400 nm.***

what color will the water appear relative to how it looks without the oil present *

Visible light 700 → 400 nm
↑ Red orange ↑ Blue, violet



Solve for constructive interference for reflected light. This tells us what frequency is "removed" from TRANSMitted light.

at ① → 180° phase change for reflected light

at ② → No phase change for reflected light

So, need $2t = (m + \frac{1}{2})\frac{\lambda}{n_{oil}}$ to solve for λ that is constructively reflected

$m = 0, 1, 2, 3 \ldots$

$$\frac{(2)(540\times10^{-9})(1.45)}{(m+1/2)} = \lambda$$

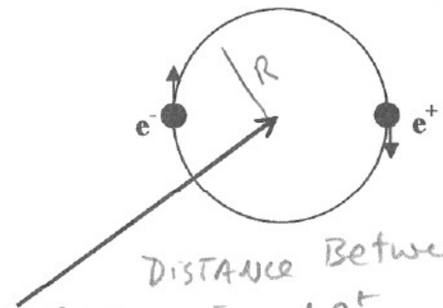
$m = 0 \rightarrow \lambda = 3132$ nm
1 → → 1044 nm
2 → → 626 nm orangish
3 → → 447 nm Blue violet

Orange + Blue violet light removed

→ leaves WATER looking more greenish

Problem 8 (15 pts, show work/logic to get credit):

Positronium is an "atom" made up of an electron and a positron (which is a positively charged electron). Since the two particles have the same mass, they orbit each other about the center of mass as shown below. Derive and circle the correct expression for the allowed energy levels for the quantized states in this system using assumptions similar to those used in the Bohr model of the atom.



a) $E_n = -\frac{mk^2e^4\pi^2}{2h^2n^2}$ b) $E_n = -\frac{n^2h^2}{ke^2\pi^2m}$ c) $E_n = -\frac{n^2h^2}{4\pi^2m^2}$

* d) $E_n = -\frac{3mk^2e^4\pi^2}{8h^2n^2}$ e) $E_n = -\frac{mke^2\pi}{2hn}$

DISTANCE Between e^- and e^+ is 2R

Force eqn

$$\frac{ke^2}{(2R)^2} = \frac{mv^2}{R}$$

Coulomb — Centripetal Force

$n\lambda = 2\pi R$

Quantization Condition

$$n\frac{h}{p} = 2\pi R \Rightarrow n\frac{h}{mv} = 2\pi R \Rightarrow v = \frac{nh}{2\pi Rm}$$

$$\frac{ke^2}{4mv^2} = R \rightarrow R = \frac{n^2h^2}{ke^2\pi^2m}$$

$$\text{PE of system} = -\frac{ke^2}{2R}$$

$$KE = \frac{1}{2}mv^2 = \frac{1}{8}\frac{n^2h^2}{\pi^2R^2m} = \frac{1}{8}\frac{n^2h^2k^2e^4\pi^4m^2}{\pi^2m\,n^4h^4}$$

$$KE = \frac{1}{8}\frac{k^2\pi^2e^4m}{n^2h^2}$$

$$PE = -\frac{k^2e^4\pi^2m}{2n^2h^2}$$

$$E_{TOT} = KE + PE = \boxed{-\frac{3}{8}\frac{k^2\pi^2e^4m}{n^2h^2} = E_n}$$ for $n = 1, 2, 3, \ldots$

Given the energy levels you have derived, how is it possible to distinguish whether a sample is made up of hydrogen or positronium "atoms"?

$E_n\big|_{\text{Positronium}} \neq E_n\big|_{\text{Hydrogen}}$ $\Rightarrow$ Spectral lines will be different